Scintillation light detection in the LArIAT TPC

New Perspectives 2015,

Pawel Kryczynski, Fermilab/INP PAS
for the

Collaboration

Outline

- What is LArIAT? (also see previous talk by E. Gramellini)
- Light Detection system in LArIAT
- Creating the optical simulation
- First results of calibration

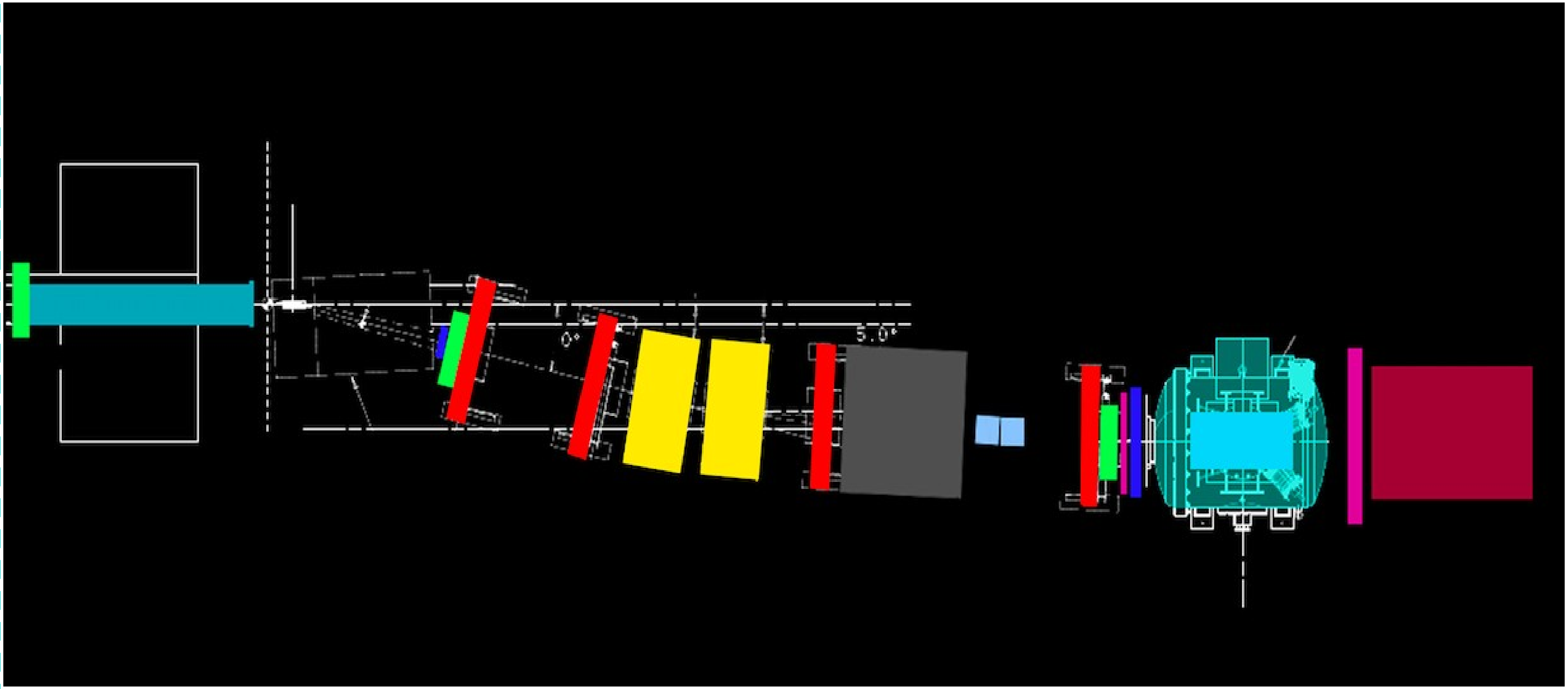
What is LArIAT

•Small (by size of apparatus and collaboration), but important **part of the US-based neutrino program** (not really a neutrino experiment though!)

•Calibration of LArTPC response for other neutrino experiments (μBooNE, SBND, DUNE...) in a controlled environment

•Currently taking data in the Fermilab test beam

What is LArIAT



A LArIAT beamline – screen from our control display, adapted by E. Gramellini

LArIAT technology goals

•In addition to former: LArIAT is an important test stand for the simulation, analysis and reconstruction software to be used in other neutrino experiments – LArSoft, art-DAQ

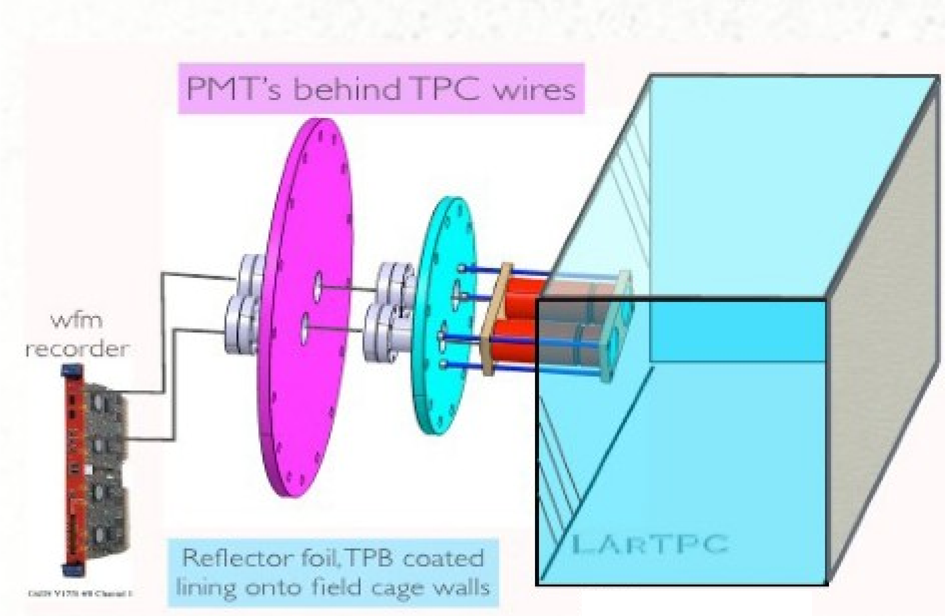
•Optical detectors added to its TPC not only as a trigger element– LArIAT will test the capabilities of scintillation light to determine calorimetric and particle ID methods, i.e. Pulse Shape Discrimination

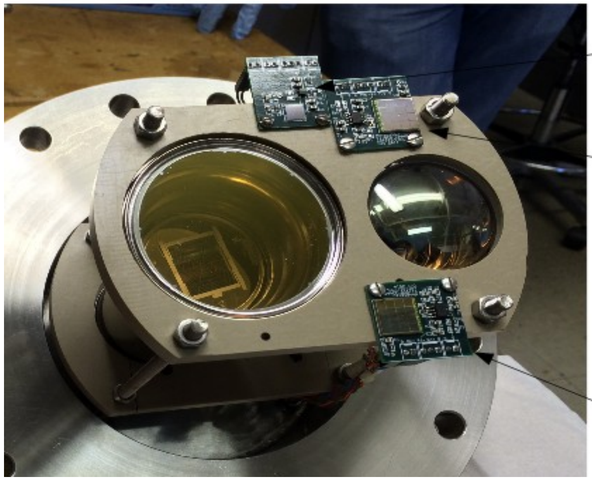
Photodetectors

•Photodetectors installed in the TPC behind the wires

•2" and 3" cryogenic PMTs of different quantum efficiency
• 3 SiPMs

•Walls lined with TPB (wavelength shifter) + reflector to make light yield uniform (and the light - visible for our detectors)

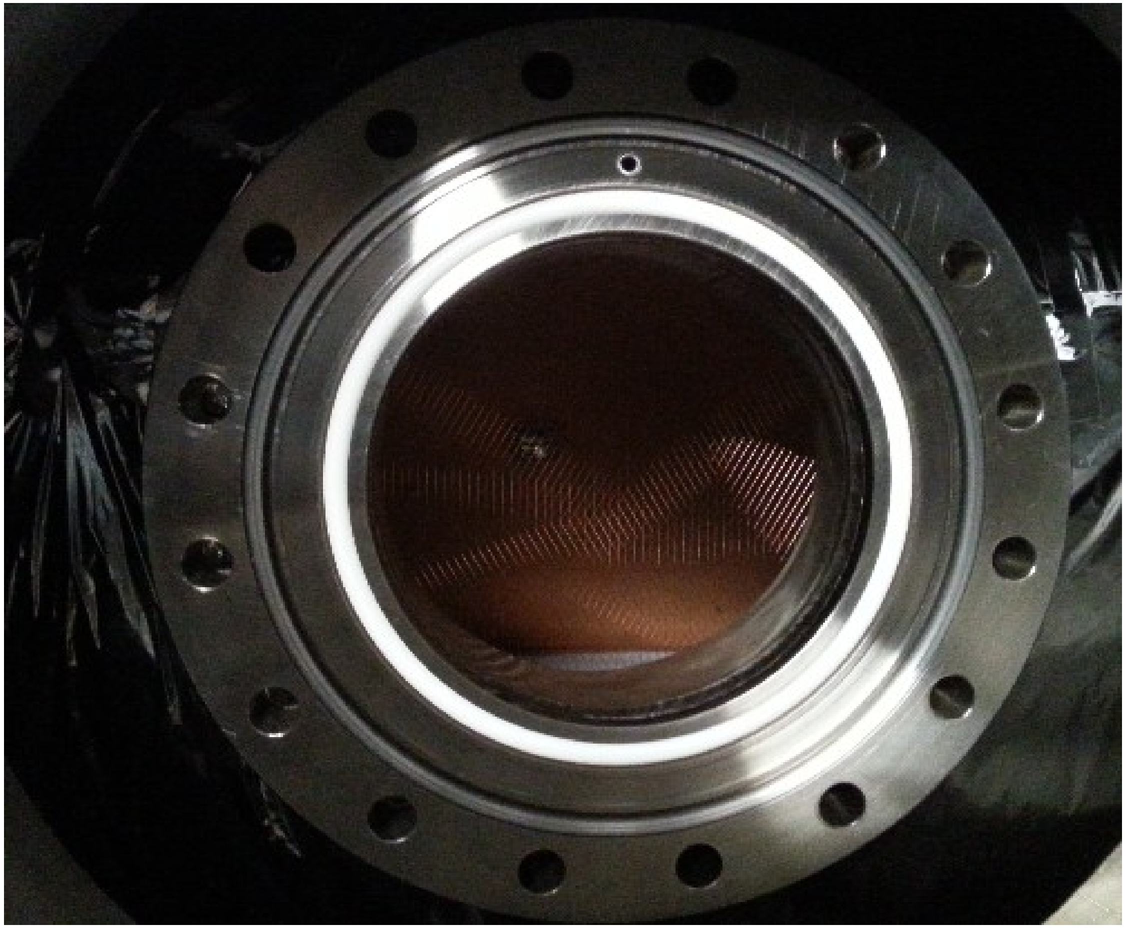




Light Detection System

- Running such a system has its challenges:
  - Diverse materials with different optical properties
  - How do we get enough light, but not too much?
  - System has to be thoroughly calibrated and this effort can be helped with detailed simulations
  - Different detectors may cross-talk with each other

Light Detection System



TPC as seen by the PMTs – through the wire planes

Light Detection system simulations

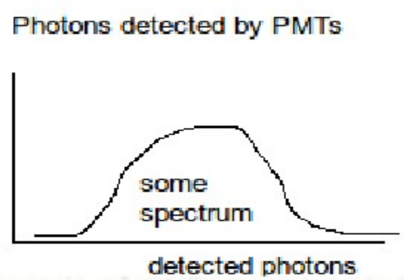
•Liquid argon may produce 40 photoelectrons per each keV of deposited energy – hard to simulate them at neutrino energies (GeV range)

•A solution - an optical lookup library built before performing full simulation (proposed in LArSoft by B.J.P. Jones, MIT)

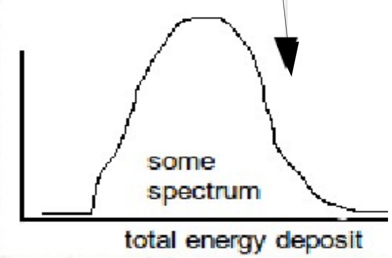
•Wavelength shifting capability and optical material properties added to LArSoft – using published data and measurements at Cracow University of Technology

Light Detection system simulations

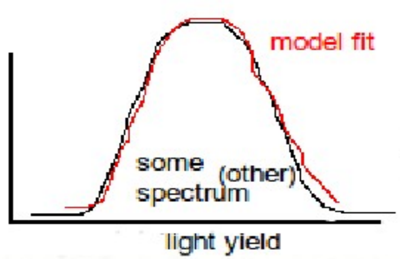
- For each event, count detected photons



- From MC truth information, get step-by-step sum of total energy deposited by incoming particle

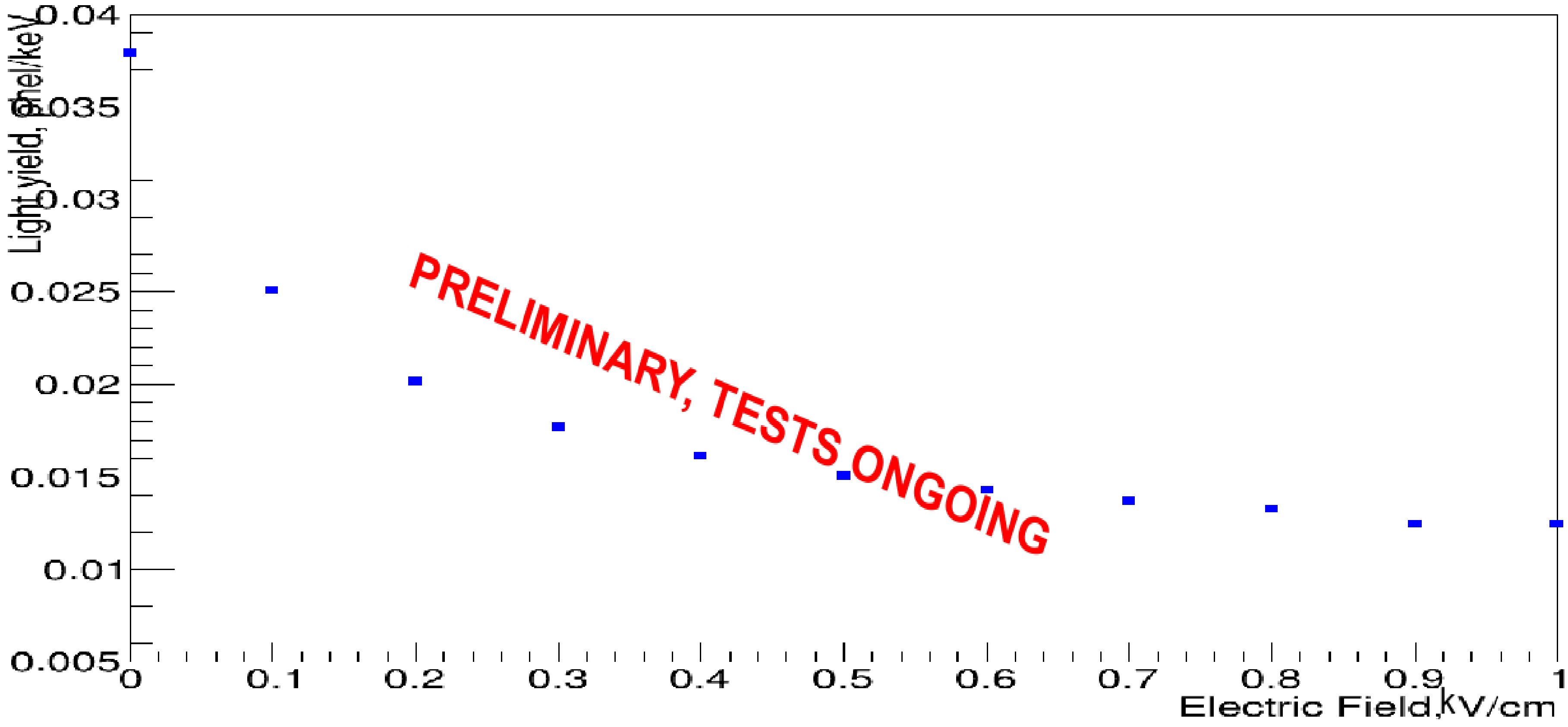


- Divide detected photon count by energy deposit for each event



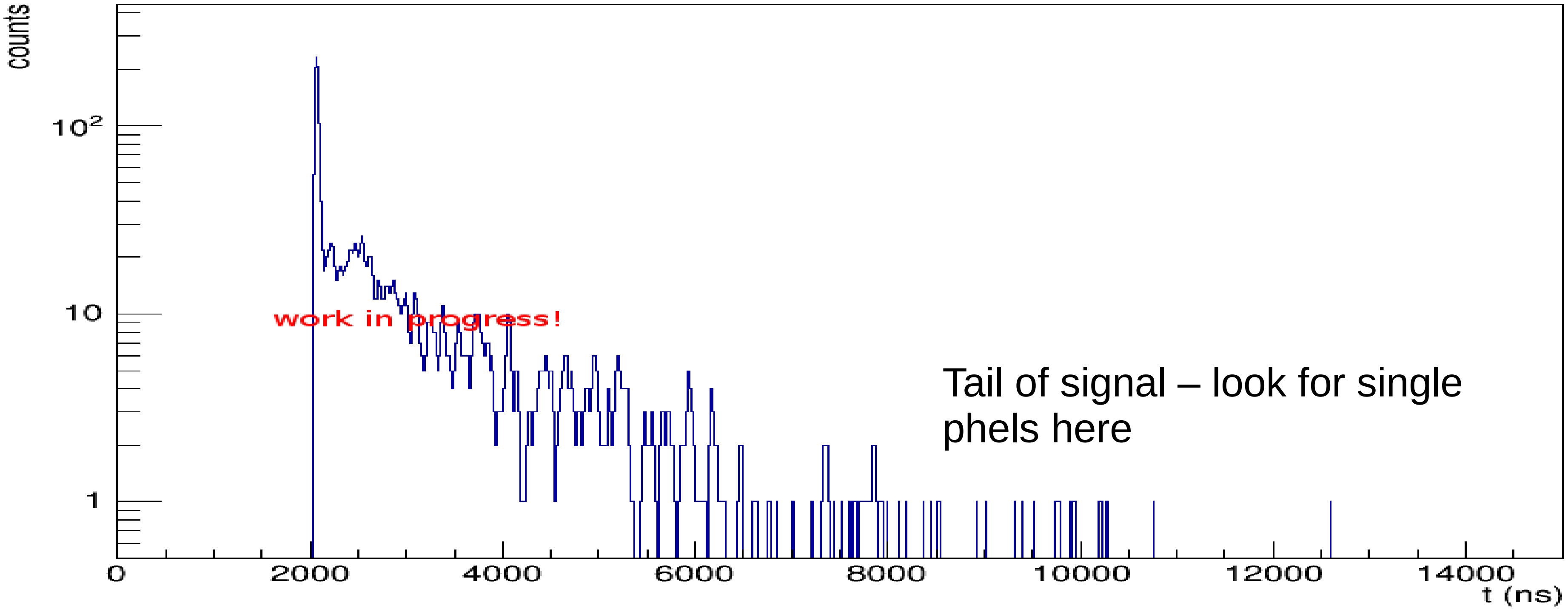
  - Central point of the fit is the estimate for light yield
  - Do this for different electric field settings

Light Detection system simulations – light yield value



Simulating the Light System: Electronics Response

•Simulating the new electronics in LArSoft -> reproducing parameters like: sampling rate (1GS/s), signal length etc. - work still in progress
•Uses photon arrival time and single electron shape (analytic or measured) to generate waveform

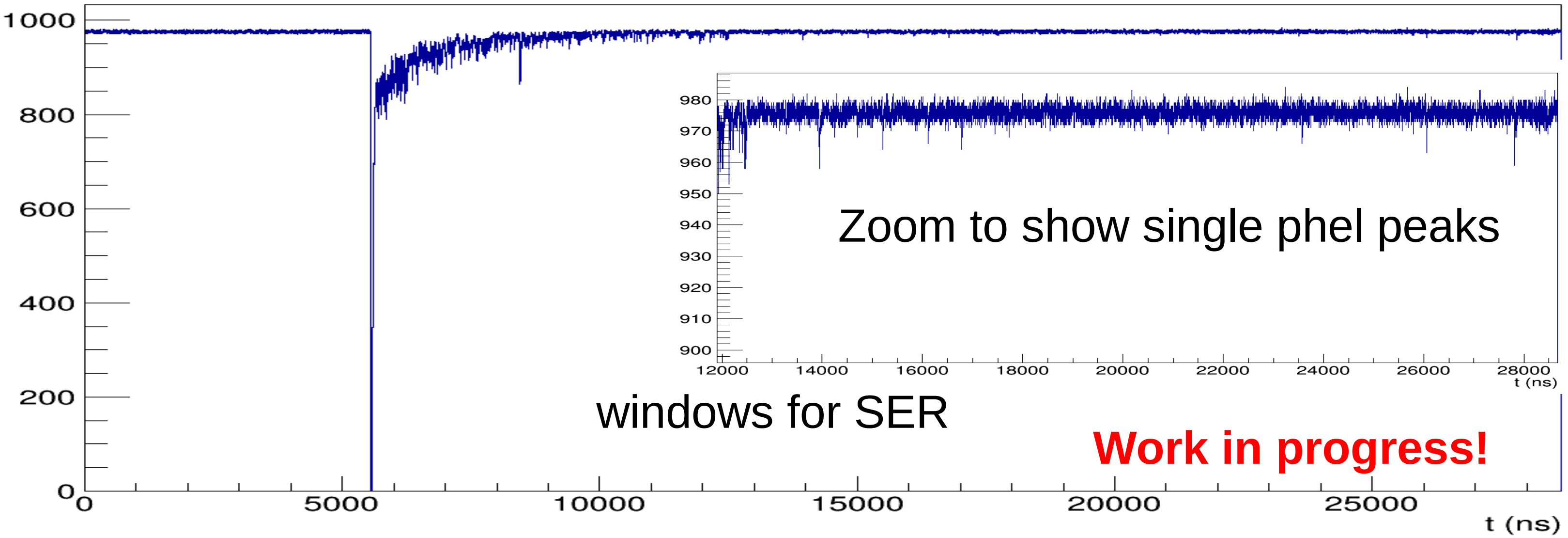


Calibrating the Light System: Single Electron Response

•Gain of the PMTs is calibrated via the single photoelectron response

•in liquid argon, we can calibrate them in-situ thanks to late scintillation light (Single phel found in tails of signals – see below)

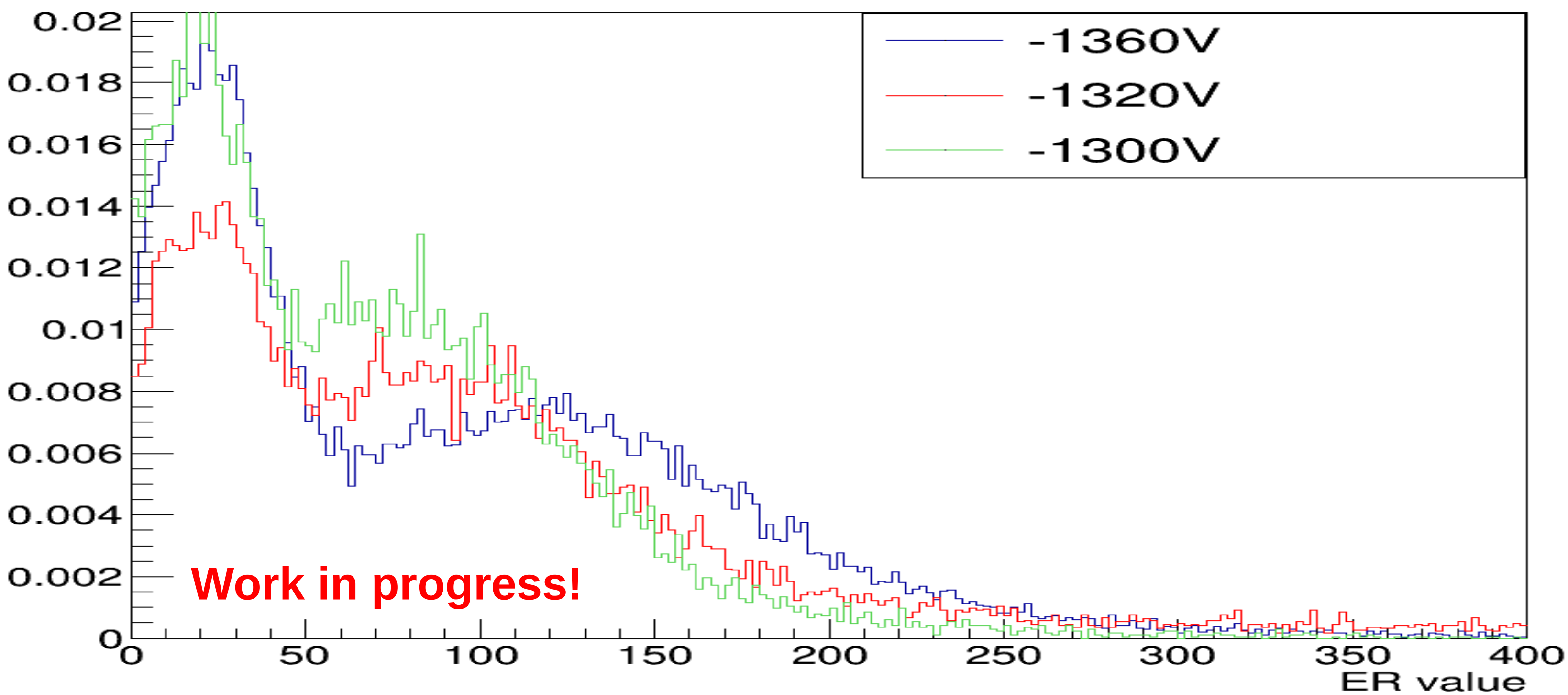
•Preliminary results for 2'' PMT



Single photoelectrons in a tail of the signal

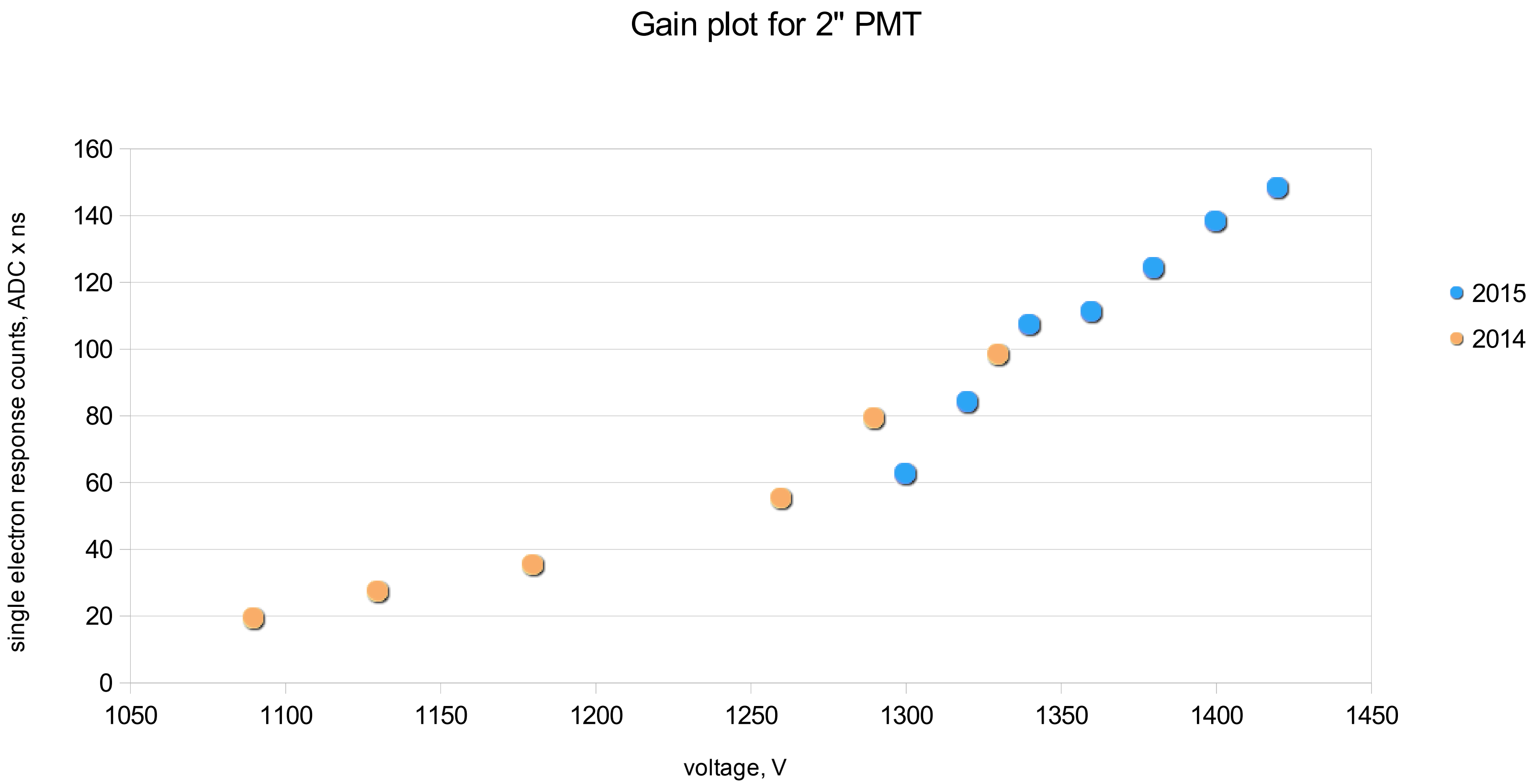
Calibrating the Light System: Single Electron Response

- SER distribution changes with the voltage on 2" PMT – changing with increasing voltage as expected



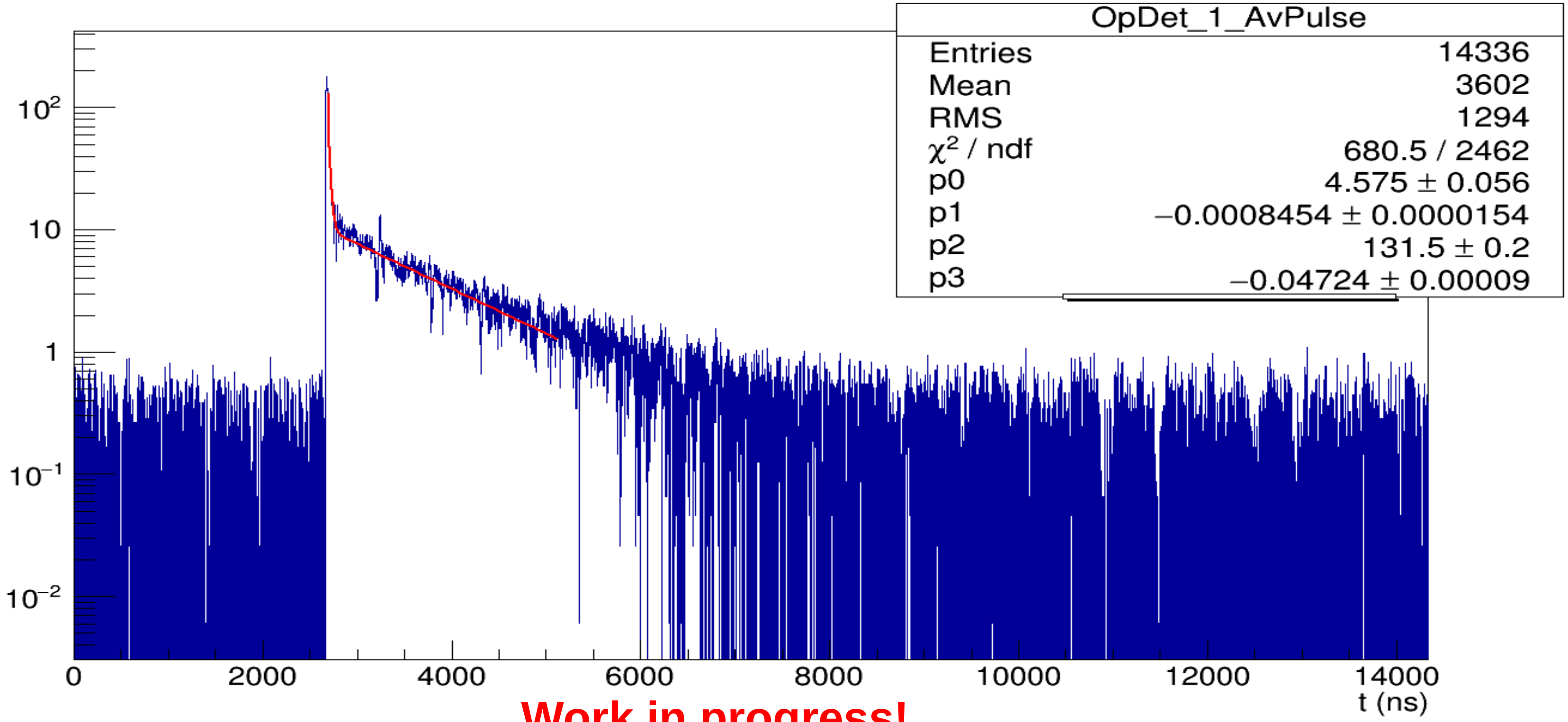
Calibrating the Light System: Gain Curve

- ...which allows for making gain plot



Calibrating the Light System: Average Waveforms

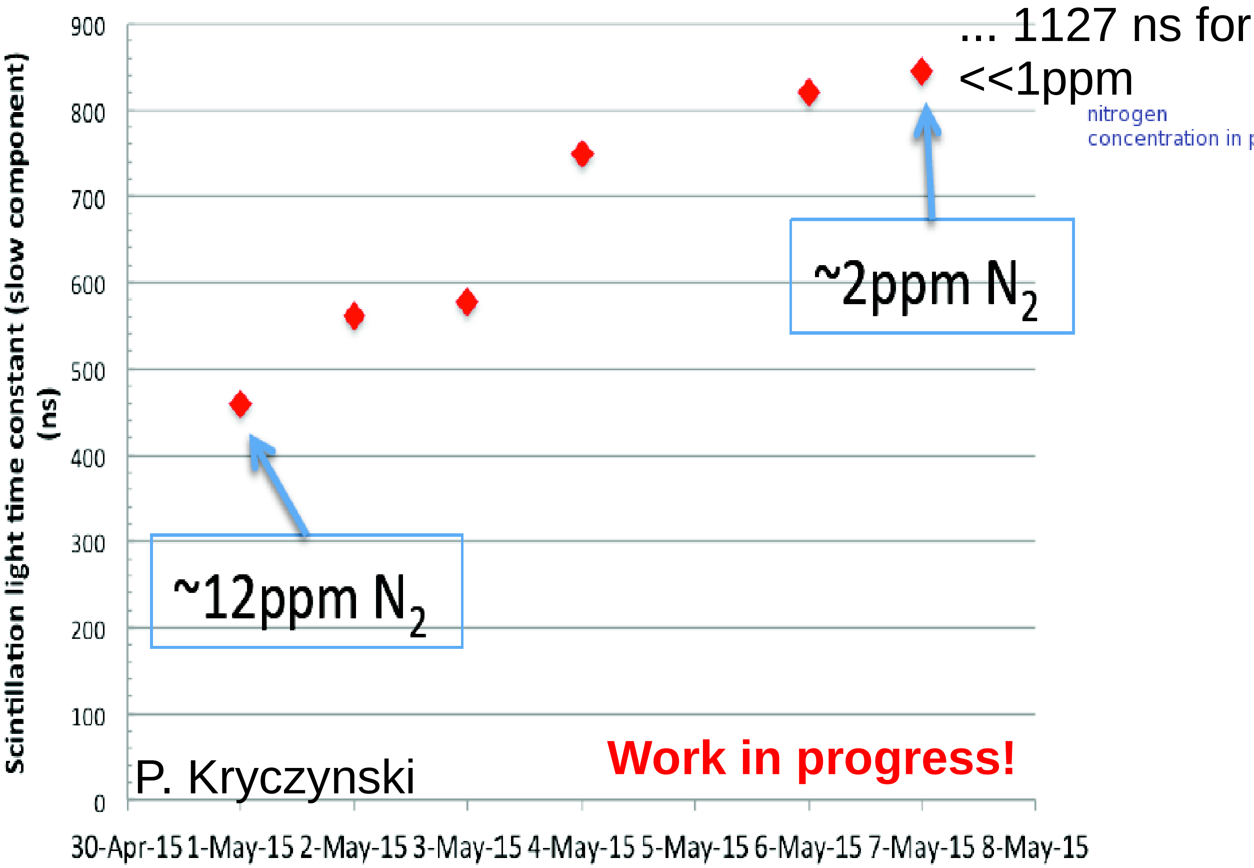
- Fitting the average waveforms with a sum of exponentials gives an estimate of argon purity

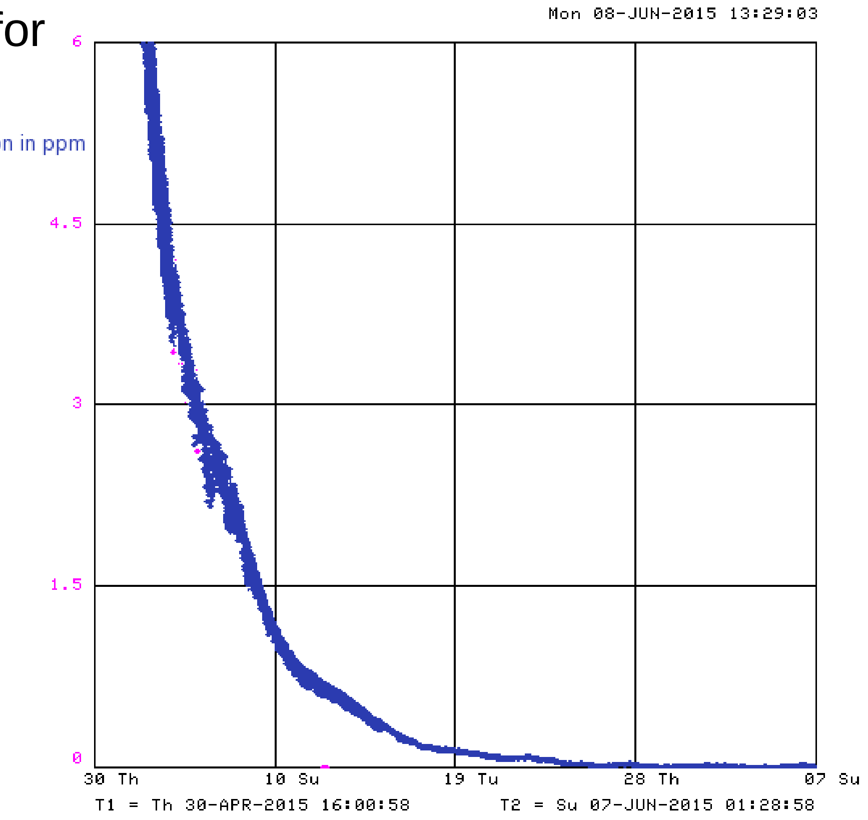


Work in progress!

Light Detection system calibration

- average waveform fitted with exponential functions
- decay time of third component gives an estimate of argon purity
- Correlated with nitrogen concentration in LAr as measured by the gas analyzer





Light Detection system calibration

- average waveform fitted fitted with exponential functions
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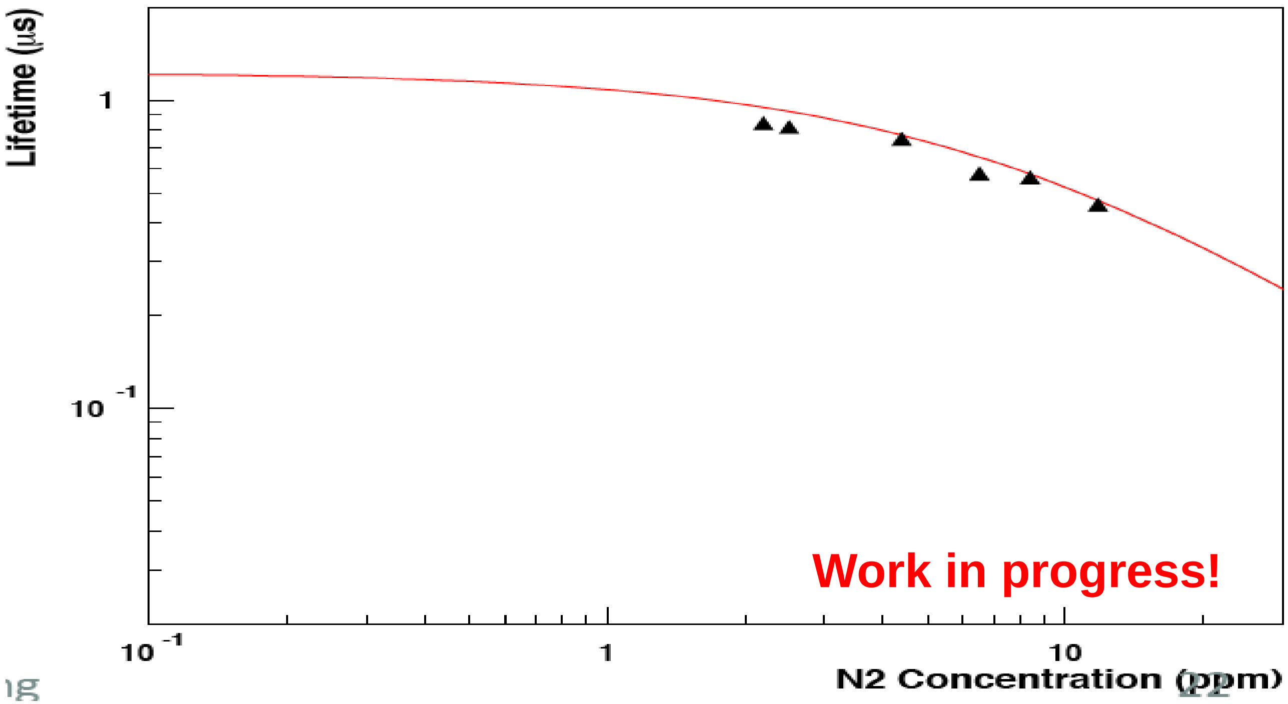

LArIAT collaboration

Summary

- LArIAT light detection system is running
- Work in progress to debug all elements of the system
- Results will feed back into the simulation
- Stay tuned for more results!

References

1)Used available information about detector simulation details e.g: JINST 7 P05008 (reflectances estimated from measurements [11] + http://refractiveindex.info and refs. Therein), G.M. Seidel, et al.,Nucl. Instr. and Meth. A 489 (2002)189; arXiv:1108.5584 [physics.ins-det]; Journal of Luminescence 81 (1999) 285}291; next.ific.uv.es (e.g code by J Martin-Albo, F Monrabal and others); arXiv:1304.6117v3 [physics.ins-det]; „Optical characterization and GEANT4 simulation of the light collection system for the WArP 100 liters detector: analysis of the event reconstruction capability", F. Di Pompeo PhD thesis

2);http://gentitfx.fr/litrani/AllModules/FitMacros/RIndexRev_vm2000.C.html and refs. Therein

3)Argon scintillation parameters change in NEST (e.g scintillation yield -> 40k ph/keV to match LArSOFT settings, decay times of components according to measurements) tested

4)Geant4 Developments and Applications, J. Allison et al., IEEE Transactions on Nuclear Science 53 No. 1 (2006) 270-278 and refs therein

5)Geant4 - A Simulation Toolkit, S. Agostinelli et al., Nuclear Instruments and Methods A 506 (2003) 250-303 and refs therein

6))arXiv:1311.6774 [physics.ins-det] and https://cdcvs.fnal.gov/redmine/projects/larsoft/wiki

7)Optical Simulations in LArSoft - Technical Manual, Ben Jones, Massachusetts Institute of TechnologyDecember 12, 2012, MicroBoone document 2313-v1

8) Szydagis et al., Enhancement of NEST Capabilities for Simulating Low–Energy Recoils in Liquid Xenon, 2013 JINST 8 C10003 and refs. Therein

9)arXiv:1412.4417 [astro-ph.IM]

10) R. Acciarri et al.,Tests of PMT Signal Read-out of Liquid Argon Scintillation with a New Fast Waveform Digitizer,2012JINST 7 P07003, arXiv:1203.1371

11) I would like to give my thanks to dr. J. Jaglarz and dr. N. Nosidlak (Cracow University of Technology)for making the measurements of G10 and copper foils reflectance possible. Experimental setup used is described in J. Jaglarz et. al. „Diffuse scattering in polyazomethine thin films", POLIMERY 2009, 54, nr 1... and refs therein

12)Doktorant otrzymał stypendium w ramach Krakowskiego Konsorcjum „Materia-Energia-Przyszłość" im. M. Smoluchowskiego w ramach dotacji KNOW.

13)Thanks to the LArIAT group, especially A.Szelc (Univ. Of Manchester), Jennifer Raaf (Fermilab), Will Foreman (University of Chicago) and Roberto Acciarri (Fermilab)

Thank you

And you

LArIAT collaboration, photo by C. Arnold, Fermilab, fnal.gov

And you

Calibrating the Light System: Single Electron Response